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Methods of Measuring Small Voltages

By the Engineering Department, Aerovox Corporation

Since the publication of our paper *Methods of Measuring High Voltages* (*Aerovox Research Worker*, January-February 1945), we have received a sufficient number of requests for a *resumé* of accepted methods of measuring small voltages to justify a special paper on that subject. As a sequel to the article on high-voltage measurements, we devote the following pages to a discussion of the instruments employed to make these so-called "millivolt measurements."

While, with certain exceptions, the instruments and methods employed for the measurement of small d. c. voltages resemble in most part those employed for checking small a. c. voltages, the two differ sufficiently in close respects to warrant separate discussions.

Since a large number of experimenters will prefer to use particular apparatus already in their possession for low voltage measurements, this article will attempt to cover most of the commonly used, as well as special equipment.

INSTRUMENTS FOR D. C. MEASUREMENTS

d'Arsonval Meters. Rugged, movable-coil meters which may be used for small d. c. voltage measurements are available either as d. c. millivoltmeters or d. c. microammeters. The latter type is basically a millivoltmeter, although it is provided with a scale graduated in current units.

In the group of meters obtainable in laboratory-table and panel-mounting styles, the most sensitive movement gives a 1 millivolt full-scale deflection. This movement has a resistance of 5 ohms and draws 200 microamperes at full scale.

Accuracy of indication in the portable meter is 1%, although 2% of full scale is common for the panel-mounting instruments used in radio testing. The scales are divided into 50 divisions, each equal to 0.01 mv or 10 μv. The smallest accurately-read deflection is one-half of a division, which is equal to 5 microvolts.

More common than the 0-1 d. c. millivoltmeter is the 0-5 microampere d. c. microammeter. The movement of the latter has a d. c. resistance of approximately 4000 ohms, which indicates that the meter basically is a 0-20 millivolt d. c. millivoltmeter. This instrument has the advantage that it presents a high resistance to the low-voltage source, resulting in reduced loading effects.

The original 0-5-microampere scale may be re-marked to indicate 0-20 mv, or a new scale of the same dimensions may be drawn. Each of the fifty scale divisions will be equal to 0.2 mv (200 μv), the smallest accurately-read deflection (½ scale division) being equal to 0.1 mv (100 μv). This is about the same sensitivity per scale division that may be expected of the small, portable laboratory galvanometers commonly employed as null detectors in d. c. Wheatstone bridges.

Suspension-Type Meters. Ultra-sensitive laboratory microammeters of the semi-suspended type are obtainable with full-scale deflections as low as 0.25 microampere, and may be used for the measurement of small voltages. One well-known 0-0.25-μa instrument has an internal resistance of 12,000 ohms. Corresponding full-scale deflection in terms of voltage thus is 3 mv. The smallest accurately-read deflection of this meter (½ scale division) is equal to 12 microvolts.

Another model of the same type instrument is an ultra-sensitive d. c. millivoltmeter having a full-scale deflection of 0.12 mv. The internal resistance of this meter is 10 ohms. The

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smallest accurately-read deflection (½ scale division) is equal to 0.5 μv.

The ultra-sensitive, semi-suspended type of meter usually has an accuracy of 2% of full scale. However, they are said to exceed their guarantee to the extent of showing 1% accuracy in most portions of the scale.

Sensitive Laboratory Galvonometers. Suspension-type laboratory galvanometers of the lamp-and-mirror type are obtainable with sensitivity as good as 0.05 μv per millimeter of deflection (based upon 1 meter separation between the scale and galvanometer mirror). A typical instrument of this rating has a total internal resistance (coil, suspension, and damping resistor) of 26 ohms, and its scale has 500 one-millimeter divisions. Full-scale deflection is 25 microvolts.

When higher internal resistances are required, a selection may be made from other galvanometers of the full suspension type having total internal resistances of the order of 10,000 ohms. One 10,500-ohm instrument gives a deflection of 5.25 μv/mm for a scale-mirror separation of 1 meter.

Because of the relative fragility of the suspension-type of galvanometer, particularly as regards their suspensions, and their extreme susceptibility to the damaging effect of transients, this instrument may be employed safely for the measurement of small voltages only in circuits protected from damaging surges and accidental overload.

Coblentz Galvanometer. While this instrument is of the lamp-and-mirror type, it differs from the moving-coil type of galvanometer in that it is of the astatic variety, consisting of a moving magnet in iron-encased coils.

The Coblentz galvanometer is more sensitive than moving-coil instruments; one commercial type having a sensitivity of 0.002 μv per mm scale division, for a scale-to-mirror separation of 1 meter, and an internal resistance of 2½ ohms.

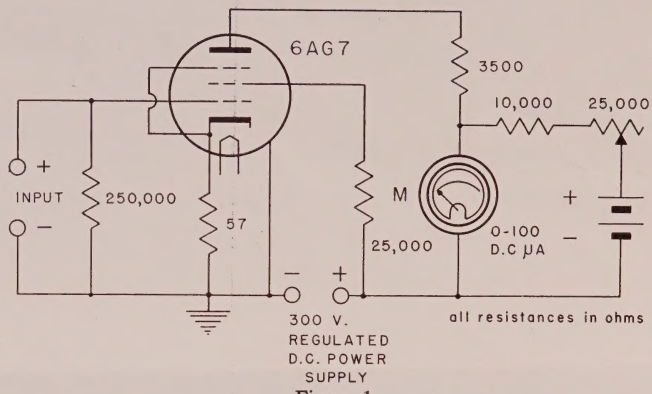

Figure 1

D. C. Amplifier. When necessity or choice dictates use of a more rugged, high-range voltmeter for measurement of small d. c. voltages, a suitable d. c. amplifier must be interposed between the meter and the voltage source. An amplifier may be employed in this way to raise voltages of 1 mv or less to values high enough to actuate a standard d. c. voltmeter such as is used for ordinary electrical testing, or to deflect a d. c. milliammeter connected into the plate circuit of the last amplifier tube. The amount of amplification required will be governed by the magnitude of voltage to be measured and the size of the meter scale (full-scale deflection). One stage will suffice in some cases, while in others, a multi-stage amplifier will be necessary. Required amplifier gain may be determined simply by dividing the desired voltmeter deflection by the small voltage value. Both values must be in the same class of units, i. e., both volts, millivolts, or microvolts.

A typical high-transconductance, single-stage amplifier with indicating microammeter is shown in Figure 1. The 6AG7 pentode has a transconductance (G_M) of 11,000, which is to say that a 1-mv potential (E_g) applied to the grid-cathode INPUT terminals will produce a plate current shift (dI_p) of 0.011 ma. If meter M is a 0-100 microampere d. c. microammeter, a 9.9-mv input potential will produce full-scale deflection. The smallest accurately-read deflection (½ scale division) will correspond to 0.198 mv (198 μv) if the microammeter has 50 scale divisions. The ideal plate current change to be expected is seen to be equal to $(G_M E_g)/1000$, where the plate current change is in milliamperes, G_M in micromhos, and E_g (the applied "unknown" voltage) in volts.

With no unknown voltage applied to the INPUT terminals, deflection due to static plate current flow is balanced out by adjusting rheostat R to return the microammeter pointer to zero. Instead of the bucking battery, a bridge circuit may be worked out to include the rheostat as one arm and the plate-cathode resistance of the tube as another arm.

Measurement of smaller voltages or use of a larger indicating meter will require higher amplification. Figure 2 shows the basic arrangement of a multi-stage d. c. amplifier usable for this purpose.

While batteries are shown here for the sake of simplicity, the various tube electrode potentials usually are obtained from taps spaced properly along a voltage divider resistor supplied by a single d. c. power unit. Battery B_1 supplies grid-cathode bias for tube V_1; B_2, screen voltage for V_1; B_2 and B_3 in series, plate voltage for V_1; B_4, grid-cathode bias for tube V_2; and B_5, screen voltage for V_2; and B_5 and B_6 in series, plate voltage for V_2. Voltage delivered by B_7 opposes the voltage drop across plate load resistor R_2 re-

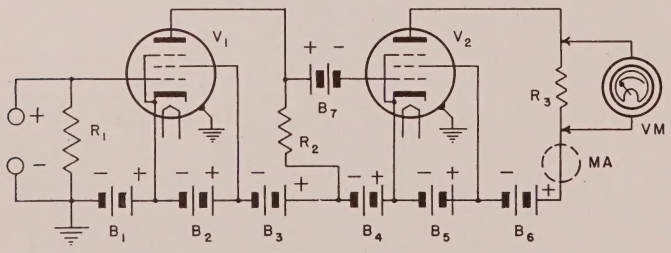

Figure 2

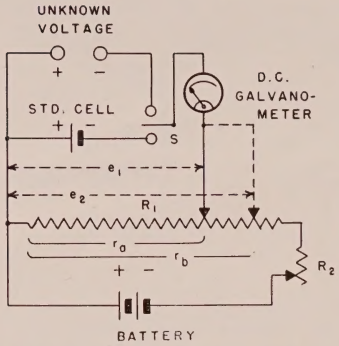

Figure 3

sulting from the steady flow of static plate current in V_1, and thereby prevents the control grid of tube V_2 from being excited constantly by this potential.

When a small d. c. voltage is applied to the input terminals of the multi-stage amplifier, an increase in the plate current of tube V_1 results, if the positive terminal of the unknown voltage source is connected to the grid of V_1. This increased plate current flowing through R_2 produces a voltage drop which is applied to the control grid of V_2 with the proper polarity to cause a plate current increase in the latter tube. This increased current flowing in plate load resistor R_3 produces a voltage drop which may be read by means of a d. c. voltmeter, VM, or the plate current increment itself may be read by means of a d. c. milliammeter, MA. In order to prevent deflection of either meter by the steady static plate current of V_2, a bucking battery must be included (as in Figure 1) in series with the voltmeter or in parallel with the milliammeter. The milliammeter scale, like that of the voltmeter, may be graduated in millivolts corresponding to the input potential range.

If the tubes and load resistors have the same specifications as those shown in Figure 1 (i. e.; G_M 11,000 and R_L 3500), the following ideal quantitative conditions might result: Application of a 1-mv d. c. potential to the input terminals results in a 0.011-ma plate current increase in V_1. This increment produces a voltage drop of 38.5 mv across the load resistor R_2, which is applied to the control grid of V_2. Application of this voltage produces a plate current increase of 0.423 ma in V_2, and a corresponding voltage drop of 1.48 v. across load resistor R_3. This last plate current increment may be made to actuate a milliammeter, MA, the scale of which is graduated in millivolts corresponding to the input potential range, or the incremental voltage drop across R_3 may be made to deflect a d. c. voltmeter, VM, the scale of which is graduated in a like manner.

It is not to be expected that the actual operation of the multi-stage d. c. amplifier is as simple as the foregoing discussion might indicate. This is especially true if a large number of tubes is employed. Small shifts in supply voltages, tube temperature, tube and component characteristics, and similar causes act singly or in combination to shift both the zero setting of the meter and voltage deflections.

Through the application of negative feedback, d. c. amplifier voltmeters have been made quite stable and sensitive. For example, one 3-stage circuit has been designed (Brumbaugh and Vance of R. C. A.) which gives a 1-milliampere deflection for 0.00022 microampere input. Another 2-tube microvoltmeter designed for the Yale University School of Medicine by Sloane Physics Laboratory of Yale permits measurements of d. c. potentials down to 5 μv and is used in studies of potentials in living organisms.

Potentiometer. By means of a laboratory potentiometer, a small voltage may be compared with a somewhat larger standard voltage, and its value determined with precision.

The basic arrangement of the potentiometer circuit is shown in Figure 3. R_1 is shown here as a single resistor, but in practical instruments it may consist of several resistance decades plus a close-reading slide-wire resistor, all connected in series. A battery is arranged to establish a current flow through R_1, the strength of this current being controlled by means of the rheostat, R_2. A variable contact on R_1 connects with a sensitive d. c. galvanometer and a single-pole, double-throw switch, S, which permits either a standard cell or the UNKNOWN VOLTAGE terminals to be connected in the circuit. Note that the standard cell (or the UNKNOWN VOLTAGE terminals) and the battery are connected in the circuit in opposing polarity.

Operation of the potentiometer is explained as follows: R_2 may be set for any arbitrary value of current flow from the battery through R_1 in which it produces a voltage drop. Switch S then may be thrown to the standard cell position; and since the cell and battery are in opposing polarity, the slider on R_1 may be set at a point where the opposing voltages reduce the galvanometer deflection to zero. At this point, the voltage drop e_1 along r_A (that portion of R_1 between the positive terminal of the battery and the sliding contact) will be equal to the voltage of the standard cell (generally 1.01830 v.).

Switch S then may be thrown to the upper position, connecting the voltage source of unknown value in the circuit in place of the standard cell. And the slider then may be moved to a new point along R_1 to reduce the galvanometer deflection again to zero. At this second null, the unknown voltage will oppose exactly the voltage drop e_2 along r_b (the new portion of R_1 between the positive terminal of the battery and the sliding contact). The unknown voltage (E_x) may be determined by means of the equation:

$$(1) \qquad E_x = \frac{E_s\, r_b}{r_a}$$

Where E_s and E_x are in volts, and r_a and r_b are in ohms.

A simpler method which enables the unknown voltage value to be read from the direct-reading resistance dials of R_1 consists of the following procedure: The resistance r_a is established at some convenient multiple, numerically, of the standard cell voltage, by pre-setting the slider. For example; r_a may be made 1018.3 ohms for a standard cell voltage of 1.01830 v. R_2 then is set for zero deflection of the galvanometer, this null indicating that the voltage drop e_1 is 1.01830 v. Each ohm of resistance along R_1 then will be equal to 0.001 v. or 1 mv. When the unknown voltage subsequently is switched-in in place of the standard cell and the second null adjustment is made, the reading of R_1 (as set) in ohms will indicate the unknown voltage value in millivolts. Similarly; if r_a is made 1 megohm, each ohm along R_1 will indicate 1 microvolt.

Commercially available laboratory potentiometers are of rugged construction for the high sensitivity that they possess. These instruments are available in several types. The Wenner potentiometer (Leeds & Northrup) has been designed expressly for the highly precise measurement of low voltages, especially thermocouple potentials. In this instrument, the fine control dial is graduated in steps of 0.1 microvolt on the low range for measurements between 0 and 0.0111110 v. within a limit of error of plus or minus (0.01%+ 0.1 μv).

INSTRUMENTS FOR A. C. MEASUREMENTS

d'Arsonval Meters. Ruggedly-constructed, sensitive, movable-coil meters for measurement of small a. c. voltages are not available in the high sensitivities associated with d. c. instruments of the same type. These meters in the panel and bench d'Arsonval group commonly are d. c. microammeter movements connected in a bridge-type oxide rectifier circuit.

The lowest range generally supplied is 0-100 a. c. microamperes, with a scale length of 50 divisions. (Internal resistance, 4000 ohms). In terms of voltage, the full-scale deflection of this meter is 400 mv. The smallest accurately-read deflection (½ scale division) is 4 mv.

Accuracy of the rectifier-type instrument is 4% of full scale on sinusoidal, or approximately sinusoidal waveforms, and at normal room temperature. The solid rectifier unit introduces a frequency error which is due mainly to its inherent shunting capacitance. This error causes the instrument reading to decrease as the frequency increases, and may amount to as much as 0.5% per kilocycle up to 20,000 cycles.

Semi-Suspended A .C. Meters. Laboratory, thermal milliammeters of the semi-suspended type are available with full-scale deflections as low as 0.5 ma. This type of instrument gives a typical voltage sensitivity of 3.75 mv per scale division, with an internal resistance of 750 ohms. Since the thermal meter employs a thermocouple instead of an oxide rectifier, it may be employed with negligible error at higher frequencies than may the rectifier-type a. c. microammeter. At still higher frequencies (e. g., radio frequencies) scale corrections may be made.

A. C. Galvanometers. Fully-suspended a. c. galvanometers of the lamp-and-mirror type are available with a typical highest sensitivity of 2 μv/mm scale division for a scale-to-mirror separation of 1 meter.

Pointer-type a. c. galvanometers for laboratory bench use offer a best accuracy of 100 μv/mm scale division.

A. C. Amplifier-Type Voltmeters. The comparative ease with which high-gain a. c. amplifiers may be built and operated simplify the task of stepping up a tiny a. c. voltage to a value high enough to actuate a standard-range a. c. voltmeter.

For frequencies between 60 and 20,000 cycles, straight resistance-capacitance-coupled amplifier circuits may be used, and the number of stages, type of tubes, and operating voltages may be chosen (with the aid of resistance-coupled tube tables found in the tube manuals) to supply the required gain. An audio amplifier with 120 db overall gain (voltage gain of 1,000,000 to 1), for example, will step 1 μv up to 1 v., a value high enough to be read on a standard voltmeter scale. In high-gain instrument amplifiers, extraordinary care must be exercised to minimize hum and noise level, since the extraneous voltages introduced by these causes may easily equal the value of the unknown potential under measurement.

One commercially-available a. f. vacuum-tube voltmeter consists of a compact, power-line-operated high-gain amplifier terminated by a frequency-compensated oxide rectifier-type a. c. voltmeter. Response of this instrument is stated as flat from 10 cycles to 150 kc. Accuracy of the instrument is 2% of full scale. Lowest indication is 20 microvolts.

For frequencies between 20 cycles and 500 kc., flat operation may be obtained in an untuned amplifier by employing a standard video amplifier circuit. (See *Aerovox Research Worker*, November 1939 for video amplifier design instructions). The upper frequency limit may be extended in these amplifiers to 4 Mc. by careful design. However, a plus or minus 1 db variation in gain may be expected between 500 kc. and 4 Mc. in even the best video amplifier. Since it is necessary to operate video amplifier stages at reduced values of plate load resistance, a large number of stages may be required for a given overall gain. In order to cover the wide band of frequencies passed by the amplifier, the terminal instrument of the video amplifier voltmeter must be a v. t. voltmeter with high input impedance.

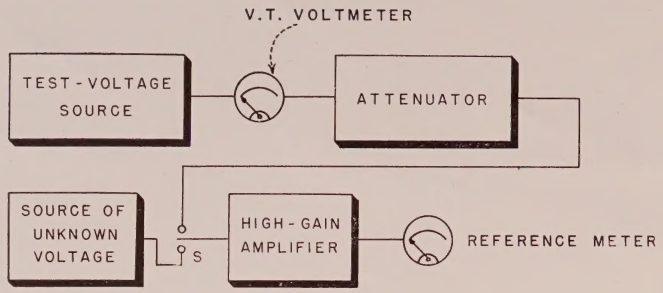

Figure 4

Tunable-Amplifier Voltmeters. For general low-voltage measurements throughout the radio-frequency spectrum, it is desirable to employ a tuned-r. f. amplifier. This unit will have no detector, but will be terminated by a low-range v. t. voltmeter with high input impedance. This is the arrangement used in the so-called channel analyzers employed in radio trouble shooting.

The tuned-r. f. amplifier type of voltmeter has the disadvantage that its gain is not constant for all frequencies in its tuning range. As a result, it becomes necessary to plot and keep a reliable curve showing gain levels at all frequencies, or to make a chart of gain-control settings which will maintain the overall gain at some fixed value.

Signal Comparison. A small a. c. voltage of unknown value may be compared with a known voltage of the same frequency and its value determined by means of a calibrated attenuator arranged in a setup of the type shown in block diagram in Figure 4.

The source of unknown voltage is connected to the s. p. d. t. switch, S, together with the test-voltage source and its attenuator, so that either source may be connected at will to the input terminals of the high-gain amplifier. Both voltage sources must have the same frequency. If the voltages are of radio frequency, the test-voltage source will be a standard radio signal generator, the high-gain amplifier an all-wave superheterodyne radio receiver (operated without automatic volume control or a beat-frequency oscillator), and the reference meter an "intensity meter" operated by the d. c. component of signal voltage in the second detector circuit. If the voltages are of audio frequency, the test-voltage source will be a variable-frequency audio oscillator, the high-gain amplifier, a resistance-capacitance-coupled audio channel having

an overall gain of 100-120 db, and the reference meter a high-impedance v. t. voltmeter connected across the amplifier output load resistor.

In operation, switch S is thrown to the left to connect the source of unknown voltage to the amplifier input terminals, and the amplifier gain control is adjusted for some convenient steady deflection of the reference meter (e. g., center scale). If the unknown voltage is at radio frequency, the signal must be tuned-in sharply with the receiver, as indicated by peak deflection of the reference meter. The switch then is thrown to the right to connect the test-voltage source to the amplifier input terminals. (If measuring r. f., the receiver is not retuned for the test signal, but is left in its first adjustment and the test-voltage source tuned, instead, for peak deflection of the reference meter). The test-voltage output control is adjusted for the *standard* attenuator input voltage (usually 1 volt R. M. S.), as indicated by the v. t. voltmeter. The attenuator then is adjusted until the deflection of the reference meter is the same as when actuated by the unknown voltage. At this point, the voltage reading of the attenuator indicates the value of the unknown voltage.

This substitution method may be employed for the measurement of very small a. f. and r. f. voltages. Standard attenuators operated at 1 volt input permit measurements between 1 microvolt and 0.1 volt.

REFERENCES

For additional information on the subject of low-voltage measurements and measuring equipment, the reader is referred to the following works:

Asset, G. Photoelectric galvanometer amplifier. *Electronics.* February 1945. p. 126.

Ballantine, Stuart. Electronic voltmeter using feedback. *Electronics.* September 1938. p. 33.

Bennett, R. D. Amplifier for measuring small currents. *Review of Scientific Instruments.* August 1930. p. 446.

Edes, F. Portable vacuum tube voltmeter for measurement of glass electrode potentials with examples of estimates. *Science.* December 15, 1933. p. 556.

Everest, F. A. High-gain wide band laboratory amplifier. *Electronics.* February 1939. p. 16.

Freeman, R. L. and Schantz, J. D. Video amplifier design. *Electronics.* August 1937. p. 22.

Gilbert, R. W. Potentiometeric direct-current amplifier and its applications. *Proceedings of the Inst. of Rad, Eng.* September 1936. p. 1239.

Ginzton, E. L. D. c. amplifier design techniques. *Electronics.* March 1944. p. 98.

Goldberg, H. High-gain d. c. amplifier for bio-electric recording. *Electrical Engineering.* January 1940. p. 60.

Harnwell, G. P. and Van Voorhis, S. N. Balanced electrometer tube for small direct currents. *Review of Scientific Instruments.* July 1934. p. 244.

Honnell, M. A. An electronic potentiometer. *Proceedings of the Inst. of Rad. Eng.* October 1942. p. 433.

Jensen, A. G. Potentiometer arrangement for measuring microvoltages at radio frequencies. *Physical Review.* July 1925.

Kelley, G. Instrument Amplifier. *Radio News.* January 1937. p. 424.

Lane, C. T. D. c. amplifier for measuring potentials in living organisms. *Electronics.* June 1937. p. 31.

Ledward, T. A. Rectifier milliammeters. *Electrician.* March 5, 1943. p. 239.

Lyons, W. and Heller, R. E. Direct reading vacuum tube millivoltmeter. *Electronics.* November 1939. p. 25.

Macalpine, W. W. Radio-frequency potentiometer. *Proceedings of the Inst. of Rad. Eng.* July 1930. p. 1144.

Murray, Charles. Thermocouple used in low voltage tube voltmeter. *Electronics.* June 1935. p. 190.

Razek, J. Vacuum tube amplifier for small direct voltages. *Journal of the Franklin Institute.* February 1935. p. 317.

Rider, J. F. *Vacuum Tube Voltmeters.* (John F. Rider; New York, N. Y.) pp. 82, 84, 85, 91, 93, 129, 130, 132.

Rogers, W. M. and Parrack, H. O. Electronic apparatus for recording and measuring electrical potentials in nerve and muscle. *Proceedings of the Inst. of Rad. Eng.* December 1944. p. 738.

Sahagen, J. Use of copper-oxide rectifier for instrument purposes. *Proceedings of the Inst. of Rad. Eng.* July 1930. p. 990.

Strong, John et al. *Procedures in Experimental Physics.* (Prentice-Hall, Inc.; New York, N. Y.). pp. 217-258, 396-448.

Sear, A. W. Amplifier for direct-current galvanometers. *Electronics.* January 1940. p. 28.

Taylor, A. H. Amplification of galvanometer deflections. *Review of Scientific Instruments.* April 1937. p. 124.

Terman, F. E. Multirange rectifier instruments having the same scale gradation for all ranges. *Proceedings of the Inst. of Rad. Eng.* March 1935. p. 234.

Turner, L. A. Balanced d. c. amplifying circuits. *Review of Scientific Instruments.* December 1933. p. 665.

Vance, A. W. Improved vacuum tube microammeter. *Review of Scientific Instruments.* December 1936. p. 489.

Woehlisch, E. Vacuum tube microvoltmeter. *Electronics.* November 1931. p. 193.

Galvanometer and potentiometer catalogues and handbooks. Leeds & Northrup Co., Cambridge Instrument Co., and Central Scientific Co.

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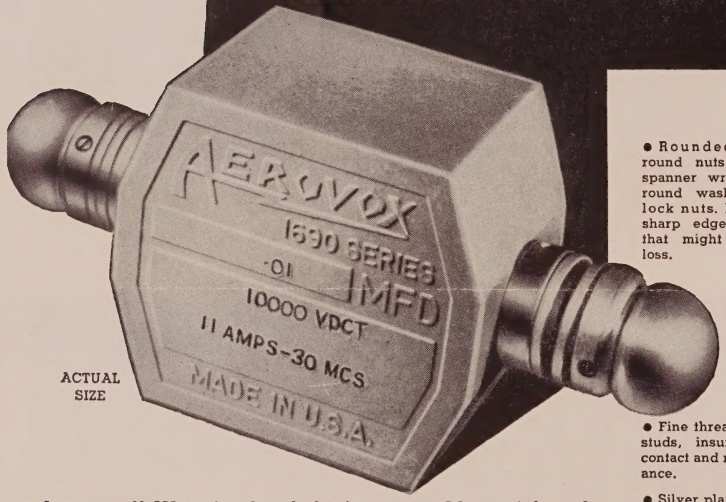

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